2. LOW DISSOLVED OXYGEN CONCENTRATION AND OXYGEN-DEPLETING SUBSTANCES

2. Low Dissolved Oxygen Concentration and Oxygen-Depleting Substances

2.1 Summary

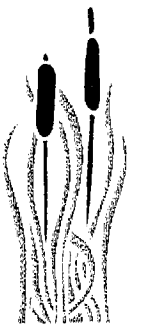
Low DO concentration and the presence of oxygen-depleting substances appears to occur in isolated areas of designated impaired water bodies. The following water bodies are listed in the January 1998 CWA Section 303(d) list as impaired from low DO concentration: Delta waterways, Sacramento River, San Joaquin River, and Bay Regions. Each region is discussed below, along with recommended approaches to solve the problems caused by low DO.

Low DO concentration and the presence of oxygen-depleting substances appears to occur in isolated areas of designated impaired water bodies.

Oxygen-depleting substances originate from a variety of sources. Common sources are degrading organic material from in-stream plants or plant matter from stormwater systems. Usually, stormwater-introduced plant material does not substantially affect DO, since most material is introduced during the wet season. However, stormwater systems also discharge during the dry season due to urban irrigation and water use. Dry season discharge is more concentrated than its winter counterpart. Agricultural drain water (irrigation return) also may carry oxygen-depleting substances. Unpermitted wastewater from industries also contains oxygen-depleting substances and nutrients. Nutrients promote the growth of algae and other water organisms. When these organisms die, they degrade and exert a demand on oxygen in the stream. Some industrial wastewater and some eroded soil in the river water contain nutrients.

2.2 Problem Statement

Oxygen depletion occurs at isolated locations in the Delta, causing DO concentrations to fall below water quality criteria (5 milligrams per liter [mg/l]). Oxygen depleting substances are found in various discharges. The substances may either exert a direct oxygen-depleting effect (i.e., biochemical oxygen demand [BOD]) or decrease oxygen by an indirect method (i.e., nutrients that cause algal growth, which eventually dies off and exerts an oxygen demand.) Low DO impairs or blocks fish migration; kills aquatic organisms, including fish; creates odors; and impairs fish reproduction and juvenile rearing.



2.3 OBJECTIVE

The objective is to correct the causes of oxygen depletion in affected areas, to reduce incidences of low DO, and to reduce the impairment of beneficial uses.

2.4 DELTA WATERWAYS

This section on Delta waterways addresses:

- the San Joaquin River near Stockton;
- Stockton tributaries, including Little Johns, Lone Tree, and Temple Creeks; and
- Urban waterways near Stockton, including Smith Canal, Mosher Slough, 5-Mile Slough, and the Calaveras River.

2.4.1 Problem Description

San Joaquin River near Stockton

DO concentrations have decreased to below the 5-mg/l standard between June and November in the San Joaquin River near Stockton. The main channel near Stockton has been identified as a candidate Bay Protection and Toxic Cleanup Program hot spot. It appears that low DO concentrations occur over a 10-mile reach of the San Joaquin River and can reach as low as 2.5 mg/l in fall. These low DO concentrations are called an "oxygen sag" and may act as a barrier to upstream migration of adult San Joaquin River fall-run chinook salmon that migrate upstream to spawn in the Merced, Tuolumne, and Stanislaus Rivers between September and December.

The main channel near Stockton has been identified as a candidate Bay Protection and Toxic Clean-up Program hot spot.

The San Joaquin River population of chinook salmon has declined, is considered a "species of concern" by the U.S. Fish and Wildlife Service (USFWS), and is a candidate for listing by the National Marine Fisheries Service. Low DO concentrations also can stress, kill, or block migration of other fish.

Oxygen depletion in the San Joaquin River is highest in late summer and fall, when high water temperature reduces the oxygen-carrying capacity of the water and increases biotic respiration rates. Low or negative streamflow past Stockton reduces dilution and mixing, which reduces re-aeration of the water. Respiring algal blooms create a high oxygen demand during these months, which exacerbates other factors. Organic carbon or nutrients from algal blooms, petroleum products, wastewater effluent, or confined animal operations deplete oxygen due to microbial digestion of the carbon. Redox (reduction/oxidation) reactions also may contribute to the oxygen depletion in the river through chemical conversion of oxygen. In addition, San Joaquin River tributaries add oxygen-depleted water after stormwater runoff events in the critical period (late summer). The tributaries introduce low DO water, and they introduce more of the same oxygen-depleting substances. Urban stormwater facilities also may contribute oxygen-depleting substances when the facilities discharge urban irrigation runoff and other urban non-point source effluent.

Oxygen depletion in the San Joaquin River is highest in late summer and fall, when high water temperature reduces the oxygen-carrying capacity of the water and increases biotic respiration rates.

Effluent from the Stockton Regional Wastewater Control Facility (RWCF) is considered to be a relatively large anthropogenic (of human origin) source of the oxygen-depleting substances in the San Joaquin River. The City of Stockton has invested considerable time and money to develop and test an accurate water quality model for the San Joaquin River near Stockton. This model is being used to investigate and evaluate alternative river management strategies. The model suggests that the RWCF is a source of BOD and ammonia in the river, but that sediment oxygen demand and algal respiration may be the dominant mechanisms causing low DO during simulated low-flow periods. The contribution of the RWCF discharge to organic sediment deposits appears relatively small compared to river loads of organic materials, although further studies are warranted to determine the factors involved.

The City of Stockton has invested considerable time and money to develop and test an accurate water quality model for the San Joaquin River near Stockton.

The City of Stockton model results also suggest that:

- A flow of 500 cubic feet per second (cfs) will increase DO by 1-1.3 mg/l.
- A temperature decrease of 2 degrees will increase DO by 1 mg/l.
- A 50% reduction of sediment oxygen demand will increase DO by 1.2 mg/l.
- An algal bloom can decrease DO concentrations by 3 mg/l.
- Removal of the entire RWCF discharge would increase DO concentration by only 1 mg/l and would not be sufficient to meet DO standards for the San Joaquin River.

The Turning Basin is another important source of oxygen-depleting substances in the San Joaquin River in late summer. Each year, the Department of Water Resources (DWR) monitors top and bottom concentrations of DO in the ship channel between Prisoner's Point and the Turning Basin. DO concentrations are lowest in the highly stratified Turning Basin, where they reach <1 mg/l near the bottom. This oxygen-depleted water moves downstream with the tide and into the main channel. The oxygen-depleted water forms a plume at the bottom of the main channel that has a minimum at the mouth of the Turning Basin before placement of the flow restriction barrier in Old River. A depression in the channel at the mouth of the Turning Basin probably accumulates oxygen-depleting substances from the bottom of the Turning Basin.

The Turning Basin is another important source of oxygen-depleting substances in the San Joaquin River in late summer.

It is uncertain whether the low DO concentrations observed in the Turning Basin near the bottom are substantially affecting DO concentrations in the San Joaquin River. The water movement between the Turning Basin and the ship channel, as well as the concentrations of DO and BOD in the water, should be more intensively monitored.

Another suspected source of oxygen depletion is unpermitted discharges of waste from concentrated animal feedlots and other less specific industrial sources. These sources are not confined to the Stockton area but are found throughout the Central Valley and beyond. They are mentioned here only because they are suspected of contributing to low DO levels in the San Joaquin River. Wastewater from such sources exert a demand on DO by introducing organic material that is consumed by micro-organisms and by introducing material that is chemically oxidized. Nutrients from confined animal facilities (and other similar wastes) contribute to algal production, which can intensify oxygen depletion as the algae respires. Confined animal facilities and some agriculture-based industry (fertilizer manufactures and users) also can introduce significant quantities of ammonia, which is lethal to fish at various concentrations, and pH. Data on unpermitted discharges are not readily available. Documenting sources in this portion of the program will include locating these unpermitted discharges.

Another suspected source of oxygen depletion is unpermitted discharges of waste from concentrated animal feedlots and other less specific industrial sources.

Several agencies have contributed in attempts to solve the low DO problem in the Stockton reach of the San Joaquin River during late summer. One strategy was to reduce oxygen depletion in the San Joaquin River by (1) controlling the effluent from the RWCF and Port of Stockton; and (2) forcing more water down the main channel with a rock barrier placed at the head of Old River, thus improving dilution and re-aeration capacity of the river. DWR constructed the barrier. The Regional Water Quality Control Board (RWQCB) has reduced the City of Stockton's effluent limit for carbonaceous BOD to 10 mg/l during this period (from 4/1 to 10/31). Pre- and post-barrier DO concentration measurements by DWR (1987-1992) in fall, however, indicate that the increased streamflow created by the barrier has little effect on DO concentrations in the oxygen sag in dry and critically dry years. The higher streamflow merely moves the DO sag

downstream. The oxygen sag persists in the channel throughout fall until cool water temperature and high mixing and streamflow from seasonal precipitation dissipate the sag. Further studies, including DWR longitudinal DO profiles, are needed to confirm findings.

Stockton Tributaries

Data from the 1980s indicate that BOD concentrations frequently exceeded 30 mg/l in Little Johns Creek, Lone Tree Creek, and Temple Creek. A maximum BOD of 126 mg/l was measured in Temple Creek. These high BOD levels are believed to be caused by waste discharge from dairies and have the potential to reduce DO concentrations.

California ranks number one in the country for dairy, number one for chicken egg production, and number three for sheep and lamb production. The total livestock and poultry value for California is $6.3 billion. With these numbers comes the animal wastes that need to be properly managed. San Joaquin Valley's 1,600 dairies with 850,000 head, create as much waste as 21 million people, yet state inspectors to regulate these activities are few. Chronic and catastrophic discharges of these wastes into Central Valley and Bay/Delta waterways contributes to problems such as nutrient loading, elevated ammonia, algal blooms, and low dissolved oxygen. Antibiotics, hormones, and selenium as drugs or feed additives also have been considered potential problems of concern.

Chronic and catastrophic discharges of animal wastes into Central Valley and Bay/Delta waterways contributes to problems such as nutrient loading, elevated ammonia, algal blooms, and low dissolved oxygen.

Urban Waterways near Stockton

Urban stormwater discharge into waterways around the City of Stockton may contribute to decreases of oxygen concentrations to less than 5 mg/l. After storms, DO concentrations as low as 0.34 mg/l have been recorded in Smith Canal, Mosher Slough, 5-Mile Slough, and the Calaveras River. The lowest concentrations occur after the first storm of the year. Low DO concentrations were associated with fish kills in the field, and laboratory tests demonstrated death of threadfin shad at 3.3– 4.7 mg/l. Urban stormwater runoff from the City of Stockton and San Joaquin County is the probable source of the low DO concentrations, but the actual sources and mechanisms are unknown. Chen and Tsai (1999) conducted a study of DO depletion in Smith Canal after stormwater events. They concluded that scour of the sediments and other constituents during storm events and the oxygen demand associated with sediments are primary factors in DO depletion. Chen and Tsai (1999) concluded that DO depletion in Smith Canal affects aquatic life within Smith Canal; but there was little impact on the San Joaquin River Deep Water Ship Channel, where Smith Canal discharges.

In urban waterways near Stockton, the lowest DO concentrations occur after the first storm of the year.

2.4.2 Approach to Solution

San Joaquin River near Stockton

Priority Actions

1. Encourage continued removal of oxygen-depleting substances from the RWCF, the Port of Stockton, and other National Pollutant Discharge Elimination System (NPDES) and Waste Discharge Requirement (WDR) permittees, to improve water quality during chinook salmon migration.

2. Develop best management practices (BMPs) with information gathered as a result of implementing the "Information Needed" portion of this section.

3. Provide technical and financial assistance and regulatory incentives for implementing BMPs to control oxygen depletion.

4. Work in conjunction with the RWCF and the Port of Stockton to develop and test new physical or operational management practices (MPs).

   Possible management actions include (1) physical mixing or other methods to decrease stratification and increase aeration in the ship channel and Turning Basin during periods of low DO, (2) changing the effluent discharge location, (3) changing the channel configuration (i.e., filling the hole at the end of the Turning Basin or deepening the main channel), and (4) constructing wetlands to increase treatment of effluent.

The goals of the proposed actions are to:

- Eliminate the occurrences of DO concentrations below 5 mg/l throughout the water column,
- Reduce the impairment or blockage of fish migration past Stockton,
- Reduce the occurrence of algal blooms,
- Reduce stress to fish due to low DO concentrations near Stockton, and
- Eliminate fish kills near Stockton.

Performance of all of these measures can be determined by appropriate monitoring programs.

Information Needed

Field studies are needed to help support the following ongoing activities:

- Quantify and identify the relative contribution of various sources of oxygen-depleting substances or oxygen-depleted water to the oxygen sag in the San Joaquin River.
- Determine the mechanisms that produce the oxygen depletion or the oxygen-depleting substances at these sources.
- Evaluate the importance of the channel depression at the mouth of the Turning Basin to the oxygen depletion.
- Compare causes and characteristics of spring and fall oxygen sag.
- Determine two- and three-dimensional flow patterns.
- Develop accurate models to determine what substances introduced to the river will produce DO sags downstream and where.
- Identify and test new MPs.
- Evaluate the effectiveness of current MPs.
- Evaluate the sources and loadings of nutrients contributing to oxygen-depleting algal blooms. (Also see Section 3, "Drinking Water.")

Existing Activities

The City of Stockton has been testing and modeling low DO in the San Joaquin River for several years. In addition, the City of Stockton is actively involved in the technical evaluation of DO conditions and alternatives for managing water quality in the lower San Joaquin River channels in the Delta. The recent report by the City of Stockton, "Potential Solutions for Achieving the San Joaquin River Dissolved Oxygen Objectives," provides a summary of recent DO conditions (1985-1996), based on the combination of DWR monitoring and routine measurements by the City.

The City of Stockton has been testing and modeling low DO in the San Joaquin River for several years. DWR has been sampling the San Joaquin River and the Turning Basin for several years and has compiled extensive data.

DWR has been sampling the San Joaquin River and the Turning Basin for several years and has compiled extensive data. Some oxygen depletion is emanating from the ship channel Turning Basin; however, the exact cause of such depletion is unknown. Studies are ongoing and expanding.

The U.S. Army Corps of Engineers (Corps) placed an aeration jet at the mouth of the Turning Basin as mitigation for DO effects from the ship channel. The aeration system has since been removed. Data may still be available regarding the efficacy of the aeration system. Any further studies should be coordinated with the Corps' efforts.

The CVRWQCB has established a watershed-based stakeholder group to assist in developing technically based comprehensive total maximum daily load (TMDL) evaluation and allocation for sources of BOD and nutrients. CALFED has awarded an $860,000 grant to determine causes and loads contributing to causes of low DO in the lower San Joaquin River. Study plans are being finalized, and work is expected to begin in various stages during the first half of 2000. The stakeholder group includes representatives from municipalities, state and federal agencies, agricultural interests, environmental interests, local industry, and academic institutions. This ongoing effort will help to identify management actions that will best achieve the established water quality objectives.

CALFED has awarded an $860,000 grant to determine causes and loads contributing to causes of low DO in the lower San Joaquin River.

Stockton Tributaries

Priority Actions

1. Assess the current water quality impairment due to high BOD in these creeks.

2. Develop new strategies to assist farmers in containing wastes on the fields, including financial incentives such as low-interest loans to upgrade their systems.

3. Undertake further efforts to enforce the WDRs of permitted and unpermitted dischargers.

The goals of these actions are to maintain DO concentrations above the 5-mg/l standard, maintain BOD concentrations below 30 mg/l, and restore natural ecosystem processes and functions in the creeks.

Information Needed

Monitoring data are needed to determine the current BOD and chemical oxygen demand (COD) loads in these creeks, the associated DO concentration, and the potential impact of current BOD levels on the ecosystem.

Urban Waterways near Stockton

Priority Actions

1. Develop strategies with the City of Stockton and other stakeholders to eliminate the DO problem.

The goals are to maintain DO concentrations in the sloughs above the 5-mg/l standard, avoid fish kills, and restore natural ecosystem processes and function.

Information Needed

More information is needed to verify that low DO concentrations are produced by urban stormwater runoff, to determine the causal substances and mechanisms of low DO concentrations, and to determine the impact of low DO concentrations on the ecosystem.

Special studies need to be conducted in 5-Mile Slough, Mosher Slough, and the Calaveras River to determine the substances and mechanisms causing low DO concentrations.

2.5 EAST SIDE DELTA TRIBUTARIES

East side Delta tributaries include the Mokelumne, Cosumnes, and Calaveras Rivers.

2.5.1 Problem Description

High deposition of fine sediments from channel disturbance on the Mokelumne River affects sediment permeability and, in combination with high water temperature, may cause low inter-substrate DO concentrations that negatively affect spawning and rearing habitat of salmonids and other fish. Other activities such as cattle grazing and agricultural runoff in the watershed could contribute to the problem. Studies are needed to determine the causes of low inter-substrate DO and the extent of impacts on aquatic life. East Bay Municipal Utilities District, in partnership with other agencies, is actively engaged in salmon habitat restoration efforts and data collection along the lower Mokelumne River. This work will add to the information base on DO problems in the river and should be expanded. CALFED supports these efforts. No information is currently available on the DO status of the Calaveras River.

High deposition of fine sediments from channel disturbance on the Mokelumne River affects sediment permeability and, in combination with high water temperature, may cause low inter-substrate DO concentrations that negatively affect spawning and rearing habitat of salmonids and other fish.

2.5.2 Approach to Solution

Priority Actions

1. Assess the extent and severity of this problem and develop strategies to reduce the problem. MPs should include decreasing the fine-sediment load.

The goal is to reduce fine-sediment loads that may cause low inter-substrate DO concentrations and impair the spawning and rearing habitat of salmonids and other fish.

The goal is to reduce fine-sediment loads that can cause low inter-substrate DO concentrations and impair the spawning and rearing habitat of salmonids and other fish.

2.6 LOWER SACRAMENTO RIVER TRIBUTARIES

2.6.1 Problem Description

Poor inter-substrate permeability and the resulting low DO concentration are primary stresses for salmon and steelhead spawning habitat in the American River. Impervious clay lenses below the gravel may contribute to the low permeability.

Poor inter-substrate permeability and the resulting low DO concentration are primary stresses for salmon and steelhead spawning habitat in the American River.

2.6.2 Approach to Solution

Priority Actions

1. Possible management actions include development of gravel enhancement programs, channel restoration programs, and river corridor assessments and MPs; and regulation of high water temperature reservoir releases.

The goals are to reduce sediment loads, which may cause low inter-substrate DO concentrations that affect salmon spawning and rearing habitat, and to establish full salmon spawning and rearing activity.

2.7 SAN JOAQUIN RIVER REGION

The San Joaquin River Region includes the Merced, Tuolumne, and Stanislaus Rivers.

2.7.1 Problem Description

The Merced, Tuolumne, and Stanislaus Rivers are tributaries of the San Joaquin River. A history of erosive land use practices and mining activities for aggregate and minerals is associated with depositing large amounts of fine sediment. High sediment deposition affects sediment permeability and causes low inter-substrate DO concentrations that negatively affect spawning and rearing habitat of salmonid and other fish.

A history of erosive land use practices and mining activities for aggregate and minerals is associated with depositing large amounts of fine sediment.

2.7.2 Approach to Solution

Priority Actions

1. Possible management actions include development of gravel enhancement programs, channel restoration programs, and river corridor assessments and MPs; and regulation of high water temperature reservoir releases.

The goals are to eliminate the low inter-substrate DO concentrations that affect salmon spawning and rearing habitat, and to establish full salmon spawning and rearing activity.

Existing Activities

The Tuolumne River Technical Advisory Committee currently is funding work, using a field technique that measures inter-substrate permeability. Such measurements would be useful in the assessment of the ecological health of stream beds.

2.8 SUISUN MARSH WETLANDS

2.8.1 Problem Description

The CWA Section 303(d) list includes Suisun Marsh as an impaired water body due to flow regulation and modification, and urban and stormwater sewer runoff. In fall 1994, DO concentrations reached as low as 1 mg/l and were frequently 4 mg/l in Goodyear, Cordelia, and Frank Horan Sloughs after the islands in the marsh were flooded for duck club management. The islands are flooded with channel water that becomes nearly anaerobic while on the islands. This island water then flows into the main channel on ebb tide and can cause low DO concentrations in the channel. Low DO concentrations were measured during the Suisun Marsh Salinity Control Test in 1994; but the severity, extent, and frequency of the problem are unknown. DO concentrations also decrease to 1 mg/l in summer and fall in the slough that receives effluent from the Fairfield-Suisun Treatment Facility. The relative contribution of urban and sewer discharge to this oxygen depletion is unknown.

The islands are flooded with channel water that becomes nearly anaerobic while on the islands. This island water then flows into the main channel on ebb tide and can cause low DO concentrations in the channel.

2.8.2 Approach to Solution

Priority Actions

1. Assess the level and ecological importance of the addition of oxygen-depleted water to the main channel.

The Suisun Marsh Preservation Agreement negotiations and Suisun Marsh Ecological Work Group need to assess the level and ecological importance of the addition of oxygen-depleted water to the main channel and develop MPs as appropriate.

The goals are to maintain DO concentrations above the 5-mg/l standard and attain natural ecosystem process and function in the marsh.

The goals are to maintain DO concentrations above the 5-mg/l standard and attain natural ecosystem process and function in the marsh.

Information Needed

A new field technique is needed to measure inter-substrate permeability. The new technique can be used to monitor inter-substrate DO concentrations and to develop an index of spawning habitat quality for each river, based on inter-substrate permeability and DO concentrations. (Biological indices and other

ecological assessments would be performed through the Ecosystem Restoration Program, in coordination with the Water Quality Program.)

Monitoring programs and special studies are needed to assess the frequency, distribution, severity, and causes of DO concentrations below 5 mg/l in Suisun Marsh; and their potential effects on ecosystem process and function.

Existing Activities

The Suisun Marsh Ecological Work Group has been assembled to address problems such as low DO in the Suisun Marsh area.